

## AMENDMENTS TO THE SPECIFICATION

Please replace the title on the front page of the PCT publication, and insert the following rewritten title:

### GAIT GENERATING SYSTEM FOR MOBILE ROBOT

Please replace the paragraph beginning at **page 70, line 21**, and insert the following rewritten paragraph:

The following will explain the subroutine processing of Fig. 11. First, in S2000, the parameter values of a second turning gait parameter (the gait parameter that specifies the second turning gait) that includes an initial (time Ts) body position Xs and a changing velocity Vxs thereof, an initial (time Ts) body posture angular velocity  $\omega_{bs}$ , and a body inclination restoring moment ZMP-converted value peak value ZMPrecpeak, which have been finally determined by the processing of S022 and S024 when the last time's gait (the gait that is one step before the current time's gait) was generated, are defined as the provisional values of the parameters of the first turning gait parameter of the normal turning gait associated with the current time's gait.

Please replace the paragraph beginning at **page 71, line 8**, and insert the following rewritten paragraph:

The aforesaid body inclination restoring moment ZMP-converted value peak value ZMPrecpeak indicates the peak value of the ZMP-converted value ZMPrec (the amount of deviation from a reference desired ZMP (the desired ZMP defined by the ZMP trajectory parameters determined in S022)) of the floor reaction force moment required for bringing the body posture close to a reference body posture in the one-leg supporting period of the robot 1 (more specifically, the period from the moment immediately after the one-leg supporting period begins to the moment immediately before it ends. Hereinafter, it will be referred to as the body inclination angle restoring period in some cases), an example thereof being shown in Fig. 20. As shown in the figure, ZMPrec is shown in the trapezoidal patterns, the peak values (the heights of the trapezoids) being denoted by ZMPrecpeak.

Please replace the paragraph beginning at **page 73, line 5**, and insert the following rewritten paragraph:

Subsequently, in S2000-1, the values of the priority parameters of the normal gait parameter excluding the initial ( $T_s$ ) body horizontal position  $X_s$ , the initial ( $T_s$ ) body horizontal velocity, the initial ( $T_s$ ) body posture angular velocity  $\omega_{bs}$ , and the body inclination restoring moment converted value ZMPrecpeak, which are search objects (search object parameters), (more specifically, the foot trajectory parameter, the reference body posture trajectory parameter, the arm posture trajectory parameter, the floor reaction force vertical component trajectory parameter, the parameter defining a floor reaction force horizontal component permissible range, and the ZMP trajectory parameter of the normal gait determined

in S022), are updated to the values that have been brought closer, by predetermined amounts, to the values determined in the aforesaid S022 from current candidate values (the values set in S2000).

Please replace the paragraph beginning at **page 73, line 22**, and insert the following rewritten paragraph:

Subsequently, in S2004-1, the values of search objects Xs, Vxs,  $\omega$ bs, and ZMPrecpeak that satisfy the boundary condition of a normal gait are determined in the exploratory manner on the basis of the normal gait parameters of the current candidates (the priority parameters of the normal gait parameter provisionally determined in S2000 that have been updated in S2002-1). This processing is carried out as shown by the flowchart shown in Fig. 12. In the following explanation of the processing (including the subroutine processing in the processing) of Fig. 12, “the current value” related to the value of each parameter of the gait parameter will be used to mean “the candidate value or the provisional value currently (at the point of time when the appropriate processing is being carried out) set” of an appropriate parameter. Further, “current xx” (xx denotes a parameter) will be used to mean “xx that is a current (at the point of time when the appropriate processing is being carried out) candidate.”

Please replace the paragraph beginning at **page 75, line 12**, and insert the following rewritten paragraph:

Subsequently, in S1202, the current values of the initial (time  $T_s$ ) body horizontal position, the initial body horizontal velocity, the initial body posture angular velocity, and the body inclination restoring moment ZMP-converted value peak value ( $X_{s1}$ ,  $V_{x1}$ ,  $\omega_{bs1}$ , and  $ZMP_{peak1}$ ), which are search objects, are taken as the initial candidates of the search objects. The values of these search objects are the values observed in the supporting leg coordinate system (the aforesaid next time's gait supporting leg coordinate system) of the first turning gait.

Please replace the paragraph beginning at **page 77, line 2**, and insert the following rewritten paragraph:

Subsequently, in S1208, a normal gait is generated using a dynamic model up to the time  $T_s+T_{cyc}$  (the terminating end of the normal gait) on the basis of the normal gait parameter that includes the current values of the initial states ( $\theta_{bs}$ ,  $X_s$ ,  $V_{xs}$ ,  $\omega_{bs}$ ,  $Z_s$ , and  $V_{zs}$ ) of the body 3 and the current value of  $ZMP_{peak}$ . This processing is executed by the subroutine processing shown by the flowchart of Fig. 13, and further, the processing of S304 of this Fig. 13 is executed by the subroutine processing shown by the flowchart of Fig. 14. Further, the processing of S412 of Fig. 14 is executed by the subroutine processing shown by the flowchart of Fig. 15. These processing will be described hereinafter.

Please replace the paragraph beginning at **page 78, line 16**, and insert the following rewritten paragraph:

Meanwhile, if the determination result of S1214 is NO, then the candidates of a plurality of (four in the present embodiment) search objects obtained by changing the values of the individual parameters by predetermined extremely small amounts  $\Delta X_s$ ,  $\Delta V_x$ ,  $\Delta \omega_{bs}$ , and  $\Delta ZMP_{peak}$  are determined in the vicinity of the values of the current search objects ( $X_s$ ,  $V_x$ ,  $\omega_{bs}$ ,  $ZMP_{peak}$ ), and the same processing as that of S1206 to S1212 is carried out to determine the boundary condition errors corresponding to the candidates of the individual search objects on the basis of the normal gait parameter that includes the candidates of the individual search objects (the normal gait parameter having the search objects of the current normal gait parameter corrected to the newly determined candidates).

Please replace the paragraph beginning at **page 79, line 4**, and insert the following rewritten paragraph:

Subsequently, in S1218, the new candidates of the search objects ( $X_s$ ,  $V_x$ ,  $\omega_{bs}$ ,  $ZMP_{peak}$ ) are determined by a search technique, such as the steepest descent method or the simplex method, on the basis of the current ( $X_s$ ,  $V_x$ ,  $\omega_{bs}$ ,  $ZMP_{peak}$ ) and the boundary condition errors corresponding to the individual candidates of the search objects in the vicinity thereof. Then, the processing from S1206 is repeated again.

Please replace the paragraph beginning at **page 79, line 12**, and insert the following rewritten paragraph:

As described above, with the ( $X_s$ ,  $V_x$ ,  $\omega_{bs}$ , ZMPrecpeak) as the search objects, a normal gait parameter that satisfies the boundary condition of the normal gait is determined in the exploratory manner. Incidentally, in the processing of Fig. 12, the priority parameters (the foot trajectory parameter, the reference body posture trajectory parameter, and the like) out of the normal gait parameter are maintained at the values at the start of the processing shown in Fig. 12.

Please replace the paragraph beginning at **page 84, line 8**, and insert the following rewritten paragraph:

The processing of S2002-1 and 2004-1 of Fig. 11 explained above is briefly said to be the processing in which the value of a priority parameter (a foot trajectory parameter or the like) of a normal gait parameter is updated by bringing it closer, by a predetermined amount, to a value determined by the processing of S022 (specifically, the processing of S100 to S110 of Fig. 10) from a current value (a current candidate value), and a new normal gait parameter that includes the updated priority parameter and that is capable of satisfying a boundary condition of a normal gait on a dynamic model is searched for. And, in this processing, ( $X_s$ ,  $V_x$ ,  $\omega_{bs}$ , ZMPrecpeak) are set as the search objects. Incidentally, the current value (the candidate value before the update) of the priority parameter of the normal gait parameter in S2002-1 is the value of the priority parameter out of the provisional value of the normal gait parameter determined in S2000. Further, in the processing of S2004-1, the provisional values determined in S2000 are used as the initial candidate values of the search objects.

Please replace the paragraph beginning at **page 85, line 1**, and insert the following rewritten paragraph:

Returning to the explanation of Fig. 11, after the aforesaid processing of S2002-1 and S2004-1, the same processing (S2002-2 and S2004-2 in Fig. 11) as the processing of S2002-1 and S2004-1 is repeated. Then, lastly, in S2004-n ( $n$  denotes the total number of repetitions), the priority parameter of the normal gait parameter is made to agree with the value determined by the processing of S022. Further, in S2004-n, as with S2004-1, based on a current candidate normal gait parameter, the values of the search objects  $X_s$ ,  $V_x$ ,  $\omega_{bs}$ , and  $ZMPrecpeak$  that satisfy the boundary condition of the normal gait are determined in the exploratory manner on the dynamic model, thus determining a new normal gait parameter.

Please replace the paragraph beginning at **page 85, line 14**, and insert the following rewritten paragraph:

In the repeated processing, the value of a priority parameter before the priority parameter is updated in S2002-k ( $k=2,\dots,n$ ) is the value of the priority parameter after the update in S2002-( $k-1$ )(in S2002-1, the value of the priority parameter before an update is the provisional value determined in S2000, as described above). The processing of S2004-k( $k=2,\dots,n$ ) is the same as the processing of S2004-1. In S2004-k, however, the values that have been set at the start of the processing of S2004-k, i.e., the values of the search objects that have

finally been searched for by the processing of S2004-(k-1), are used as the initial value candidates (the initial value candidates set in S1202 of Fig. 12) of the search objects Xs, Vx,  $\omega_{bs}$ , and ZMPrecpeak (in S2004-1, the initial value candidates of the search objects are the provisional values determined in S2000, as described above).

Please replace the paragraph beginning at **page 93, line 15**, and insert the following rewritten paragraph:

The following will explain the subroutine processing of Fig. 17. First, in S2100, the parameter values of the current time's gait parameter that include the ZMP corrected parameter "a" finally determined by the processing of S026 and S028 when the last time's gait was generated and the first peak value ZMPrecpeaka and the second peak value ZMPrecpeakb, which are body inclination restoring moment converted values, are defined as the provisional values of the parameters of the current time's gait parameter to be generated. However, the gait parameter of the last time's gait is laterally reversed when taking the parameter values as the provisional values of the parameters of the current time's gait. For example, the provisional values of the foot trajectory parameter of a supporting leg, the foot trajectory parameter of a free leg, and a ZMP trajectory parameter of the current time's gait are set to be the ones obtained by laterally reversing these parameters of the last time's gait.

Please replace the paragraph beginning at **page 94, line 6**, and insert the

following rewritten paragraph:

Here, the first peak value ZMPrecpeaka and the second peak value ZMPrecpeakb of a body inclination restoring moment ZMP-converted value obtained (searched for) in the processing of the flowchart of Fig. 17 are search object parameters indicating the two peak values of the pattern of the ZMP-converted value of a floor reaction force moment required to bring a body posture close to a reference body posture during the body inclination angle restoring period [Ta,Tb] of the current time's gait, an example thereof being shown in Fig. 21. The number of peak values of the body inclination restoring moment ZMP-converted value has been one in the case of a normal gait; in the present embodiment, however, the first peak value ZMPrecpeaka and the second peak value ZMPrecpeakb are used as the two adjustable parameters of a body inclination restoring moment ZMP-converted value so as to make the body posture angle and the angular velocity thereof at the terminating end of the current time's gait coincide with the initial body posture angle and the angular velocity thereof, respectively, of the normal gait. In the present embodiment, as shown in Fig. 21, the body inclination restoring moment ZMP-converted value in the current time's gait has a pattern combining a trapezoidal pattern in the first half and another trapezoidal pattern in the latter half of the one-leg supporting period. The peak value of the trapezoidal pattern in the first half is the first peak value ZMPrecpeaka, and the peak value of the trapezoidal pattern in the latter half is the second peak value ZMPrecpeakb.

Please replace the paragraph beginning at **page 96, line 19**, and insert the

following rewritten paragraph:

Subsequently, in S2102-1, the values of the priority parameters of the current time's gait parameter excluding the ZMP corrected parameter "a" and the first peak value ZMPrecpeak<sub>a</sub> and the second peak value ZMPrecpeak<sub>b</sub> of the body posture inclination restoring moment ZMP-converted value, which are search objects (search object parameters), (more specifically, the foot trajectory parameter, the reference body posture trajectory parameter, the arm posture trajectory parameter, the floor reaction force vertical component trajectory parameter, the parameter defining a floor reaction force horizontal component permissible range, and the ZMP trajectory parameter of the current time's gait determined in S026) are updated to the values that have been brought closer, by predetermined amounts, to the values determined in the aforesaid S026 from current candidate values (the values set in S2100).

Please replace the paragraph beginning at **page 97, line 9**, and insert the following rewritten paragraph:

Subsequently, in S2104-1, the values of search objects "a", ZMPrecpeak<sub>b</sub>, and ZMPrecpeak<sub>b</sub> that satisfy the aforesaid boundary condition (a condition in that the divergence component at the terminating end of a current time's gait agrees or substantially agrees with the divergence component at the beginning of a normal gait) of the current time's gait are determined in the exploratory manner on the basis of the current time's gait parameter of the current candidate (the priority

parameters of the normal gait parameter provisionally determined in S2100 that have been updated in S2102-1). This processing is carried out as shown by the flowchart shown in Fig. 18. Incidentally, as in the case of the explanation of the processing of the aforesaid Fig. 12, the following explanation of the processing (including the subroutine processing in the processing) of Fig. 18, "the current value" related to the value of each parameter of the gait parameter will be used to mean "the candidate value or the provisional value currently (at the point of time when the appropriate processing is being carried out) set" of an appropriate parameter. Further, "current xx" (xx denoting a parameter) will be used to mean "xx that is a current (at the point of time when the appropriate processing is being carried out) candidate."

Please replace the paragraph beginning at **page 98, line 6**, and insert the following rewritten paragraph:

The processing of Fig. 18 will now be explained. First, in S1700, the current values of the ZMP correction parameter and the first peak value and the second peak value of the body inclination restoring moment ZMP-converted value ("a", ZMPrecpeaka, and ZMPrecpeakb), which are search objects, are set as the initial value candidates of these search objects.

Please replace the paragraph beginning at **page 98, line 13**, and insert the following rewritten paragraph:

Subsequently, the loop processing of S1704 to S1716 is carried out. The processing will be schematically explained. First, in S1704, a current time's gait (a provisional current time's gait) is calculated using the current values (current candidate values) of the "a", ZMPrecpeaka, and ZMPrecpeakb, which are the search objects, and the aforesaid dynamic model. More specifically, a provisional current time's gait is calculated using the current time's gait parameter that includes the current values of the search objects, namely, "a", ZMPrecpeaka, and ZMPrecpeakb, and the current values of priority parameters, and the dynamic model. More specific processing of S1704 will be discussed hereinafter.

Please replace the paragraph beginning at **page 98, line 26**, and insert the following rewritten paragraph:

Then, in S1706 to S1716, the difference between the divergence component at the terminating end of the provisional current time's gait (the estimated landing time of a free leg foot of the current time's gait) calculated in S1704 and the initial divergence component  $q''$  of the normal gait (lastly calculated in the aforesaid S024), the difference between the body posture angle at the terminating end of the provisional current time's gait and the initial body posture angle of the normal gait (lastly calculated in the aforesaid S024), and the difference between the angular velocity of the body posture angle at the terminating end of the provisional current time's gait and the initial body posture angular velocity of the normal gait (lastly calculated in the aforesaid S024) are determined. Then, it is determined whether all the values of these differences satisfy a condition in that they

fall within permissible ranges (whether they approximate zero), and if they do not satisfy the condition, then the values of the search objects are changed. This is repeated to finally determine anew a current time's gait parameter that includes "a", ZMPrecpeaka, and ZMPrecpeakb as the corrected values of the parameters of the search objects that allows the provisional current time's gait to connect to the normal gait on the dynamic model.

Please replace the paragraph beginning at **page 101, line 4**, and insert the following rewritten paragraph:

Meanwhile, if the determination result of S1712 is NO, then the candidates of a plurality of (three in the present embodiment) search objects obtained by changing the values of the individual parameters by predetermined extremely small amounts  $\Delta a$ ,  $\Delta ZMPrecpeaka$ , and  $\Delta ZMPrecpeakb$  are determined in the vicinity of the values of the current search objects ("a", ZMPrecpeaka, and ZMPrecpeakb), and the same processing as that of S1704 to S1710 is carried out on the basis of the current time's gait parameter that includes the candidates of the individual search objects (the current time's gait parameter in which the search objects of the present current time's gait parameter have been corrected to newly determined candidates), thereby determining a set of errors ( $err_q$ ,  $\theta_{berr}$ , and  $\omega_{berr}$ ) corresponding to the candidate of each search object.

Please replace the paragraph beginning at **page 101, line 19**, and insert the following rewritten paragraph:

Subsequently, in S1716, the new candidates of the search objects ("a", ZMPrecpeaka, and ZMPrecpeakb) are determined by an exploratory technique, such as the steepest descent method or the simplex method, on the basis of the current ("a", ZMPrecpeaka, and ZMPrecpeakb) and the sets of errors ( $\text{err}_q$ ,  $\theta_{\text{berr}}$ , and  $\omega_{\text{berr}}$ ) corresponding to the individual candidates of the search objects in the vicinity thereof. Then, the processing from S1704 is repeated again.

Please replace the paragraph beginning at **page 102, line 1**, and insert the following rewritten paragraph:

As described above, with the ("a", ZMPrecpeaka, and ZMPrecpeakb) being the search objects, the new current time's gait parameter that satisfies the boundary condition at the terminating end of the current time's gait is determined in the exploratory manner. In the processing of Fig. 18, the priority parameters (e.g., a foot trajectory parameter and a reference body posture trajectory parameter) in the current time's gait parameter are maintained at the values observed at the start of the processing of Fig. 18.

Please replace the paragraph beginning at **page 104, line 24**, and insert the following rewritten paragraph:

Further, if the current time  $k$  (the time in a provisional current time's gait that is being created) is time within the aforesaid body inclination angle restoring

period, then the body angular acceleration  $\beta$  is determined by the processing of S518 to S526 such that a floor reaction force moment corresponding to the instantaneous value of a body inclination restoring moment ZMP-converted value pattern (this depends on the current values (candidate values) of the first peak value ZMPrecpeaka and the second peak value ZMPrecpeakb of the body inclination restoring moment ZMP-converted value and the current time k. Refer to Fig. 21) is generated on the dynamic model. Further, the body horizontal acceleration is determined as the difference between a body horizontal acceleration for the floor reaction force moment about a desired ZMP (the desired ZMP corrected by a ZMP correction amount) generated by the body translational mode to become zero and a body horizontal acceleration that generates a floor reaction force moment equivalent to the floor reaction force moment due to the body angular acceleration  $\beta$  on the dynamic model. Thus, the body angular acceleration  $\beta$  and the body horizontal acceleration  $\alpha$  are determined such that a desired ZMP is satisfied while restoring a body posture toward the reference body posture.

Please replace the paragraph beginning at **page 105, line 26**, and insert the following rewritten paragraph:

The processing of S2102-1 and 2104-1 of Fig. 17 explained above is briefly said to be the processing in which the value of a priority parameter (a foot trajectory parameter or the like) of a normal gait parameter is updated by bringing it closer, by a predetermined amount, to a value determined by the processing of S026 (specifically, the processing of S600 to S610 of Fig. 16) from a current value (a

current candidate value), and a new current gait parameter that includes the updated priority parameter and that is capable of satisfying a boundary condition of the current time's gait on a dynamic model is searched for. And, in this processing, ("a", ZMPrecpeaka, ZMPrecpeakb) are set as the search objects. Incidentally, the current value (the candidate value before the update) of the priority parameter of the current gait parameter in S2102-1 is the value of the priority parameter out of the provisional value of the current time's gait parameter determined in S2100. Further, in the processing of S2104-1, the provisional values determined in S2100 are used as the initial candidate values of the search objects.

Please replace the paragraph beginning at **page 106, line 19**, and insert the following rewritten paragraph:

Returning to the explanation of Fig. 17, after the aforesaid processing of S2102-1 and S2104-1, the same processing (S2102-2 and S2104-2 in Fig. 17) as the processing of S2102-1 and S2104-1 is repeated. Then, lastly, in S2104-n (n denotes the total number of repetitions), the priority parameter of the current time's gait parameter is made to agree with the value determined by the processing of S026. Further, in S2104-n, as with S2104-1, based on a current candidate current time's gait parameter, the values of the search objects "a", ZMPrecpeaka, and ZMPrecpeakb that satisfy the boundary condition of the current time's gait are determined in the exploratory manner on the dynamic model, thus determining a new current time's gait parameter.

Please replace the paragraph beginning at **page 107, line 6**, and insert the following rewritten paragraph:

In the repeated processing, the value of a priority parameter before the priority parameter is updated in S2102-k ( $k=2,\dots,n$ ) is the value of the priority parameter after the update in S2102-( $k-1$ )(in S2102-1, the value of the priority parameter before an update is the provisional value determined in S2100, as described above). The processing of S2104-k( $k=2,\dots,n$ ) is the same as the processing of S2104-1. In S2104-k, however, the values that have been set at the start of the processing of S2104-k, i.e., the values of the search objects that have finally been searched for by the processing of S2104-( $k-1$ ), are used as the initial value candidates (the initial value candidates set in S1700 of Fig. 18) of the search objects "a", ZMPrecpeaka (in S2104-1, the initial value candidates of the search objects are the provisional values determined in S2100, as described above).

Please replace the paragraph beginning at **page 110, line 9**, and insert the following rewritten paragraph:

After the processing of S030 is carried out, or if the determination result of S016 is NO, then the procedure proceeds to S032 wherein the instantaneous values of the current time's gait are determined one after another. The subroutine processing of this processing is the same as the aforesaid processing of the flowchart of Fig. 19 explained in relation to generating a provisional current time's gait. In this case, as the ZMP parameter "a" and the first peak value ZMPrecpeaka

and the second peak value ZMPrecpeakb of a body inclination restoring moment ZMP-converted value, the ones finally determined in S028 of Fig. 12 (the ones finally searched for in the processing of S2104-n of Fig. 17) are used.